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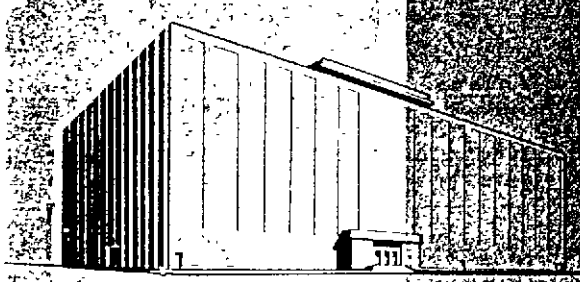
USNRDL-451

Annual Report

1954



U. S. NAVAL
RADIOLOGICAL
DEFENSE
LABORATORY

San Francisco 24, California

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CHEMICAL TECHNOLOGY DIVISION

The major effort of the Chemical Technology Division during the fiscal year was devoted to field operations since actual field conditions offered the best opportunities for acquiring additional knowledge in the fields of competence of the Division.

During Operation CASTLE, assessment was made of the radiation hazards produced by the radiation fields which resulted from the fall-out from nuclear detonations and which created potentially debilitating effects far beyond the range of its blast damage. Information concerning the transport, distribution, and properties of the fall-out was gathered. Under Projects 2.5a and 2.6a, samples and data were collected at a number of stations arrayed about the point of detonation on land and at sea. On-site measurements of the decay of short-lived radionuclides were made in mobile laboratories. Under Project 6.4, the effectiveness of countermeasures for ships in an area of fall-out was proof-tested. Two ships, fitted with instruments and remotely controlled by radio were exposed to the fall-out in Operation CASTLE. One ship was fully protected with anti-contamination devices, the other was unprotected. Direct correlation of the dosages on the two ships determined the effectiveness of the countermeasures employed.

PREPARATIONS FOR FIELD TEST

The preliminary work for Operation CASTLE in part involved the development of special devices and laboratory tests. Since 6.4 dealt with the extent of deposition of radioactive aerosols throughout the ventilation system of a ship, shipboard duct system models were constructed and tests were made to determine the deposition patterns. A continuous air sampler was devised to make time-intensity records of activity in the fall-out area. In this sampler, a 270-ft strip of filter paper passes beneath the grating at the end of a conical collimator through which radioactive particles are drawn with iso-kinetic flow onto moving paper. After exposure, the beta and gamma activity on each part of the paper are counted and the counts are fed into an Esterline-Angus recorder which plots a time-intensity graph. Also, tests of the suitability of sublimable and molecular type filters for analyzing particle sizes proved the molecular type to be more suitable for Operation CASTLE.

For Project 2.5a, a fog-sampling device was developed to obtain information on size, radioactivity, and ionic content of individual liquid aerosol particles. The fog is precipitated by an electrostatic field onto a continuously moving film which, after exposure to fall-out, is developed and analyzed. For 2.6a, an automatic water drop collector was devised to collect rain drops in flour-filled trays where they are retained as pellets of dough. After a pre-determined number of drops is collected, the device automatically changes trays. By determining the size of the pellets, the size of the water droplets could be estimated.

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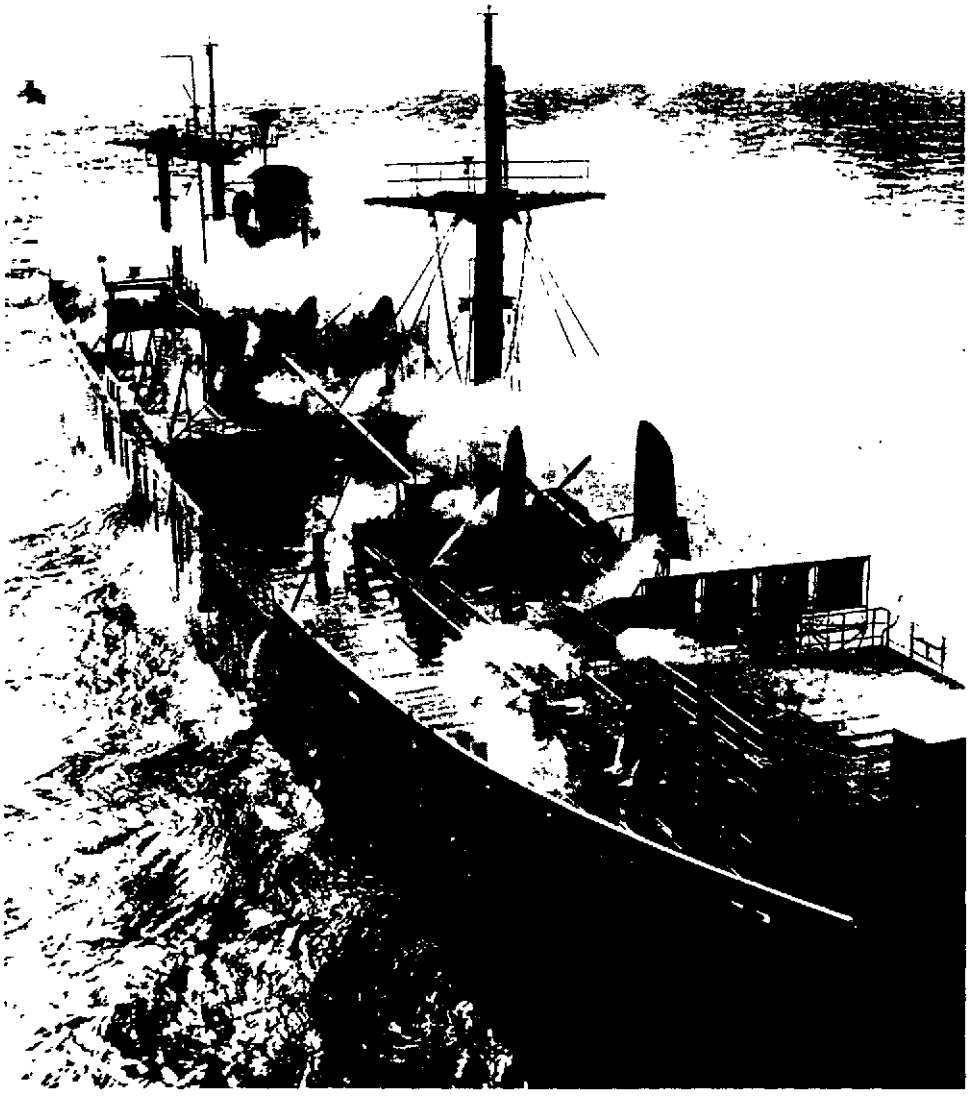

"Washdown" in Operation. The Wind, Blowing From Port, is Deflecting the Spray. On a Ship Headed Into the Wind, the Spray Would Cover the Entire Ship.

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FIELD TEST

Project 6.4 was the first proof-test of the washdown system under the conditions of an actual radioactive fall-out. Previous tests in which simulants were used had been made on a destroyer, a cruiser, and an aircraft carrier and had indicated that the washdown system would be an effective countermeasure. Two converted ships were instrumented and equipped to simulate certain critical aspects of combat ships and one was fitted with a complete washdown system. The washdown system is a series of nozzles strategically located over a ship's surfaces so that sea water from the ship's pumps could wash its surfaces with a dense spray. Both ships were sent by remote control into the fall-out area at shot time and were so maneuvered as to follow adjacent courses throughout the period of extensive fall-out. At the first indication of fall-out, the washdown system was turned on and it continued to operate during the entire fall-out period. At the end of the fall-out, both ships were returned to the anchorage point and were boarded to retrieve the records made by the various instruments.

RESULTS OF FIELD TEST

The fall-out samples for Projects 2.5a and 2.6a were analyzed to determine such data as decay rates of the gamma fields, average density of the solid particles in the fall-out, and time and rate of arrival of fall-out. The fall-out from the land surface shots was well characterized. Although little data were obtained on the nature of fall-out from overwater shots, there was evidence that this fall-out arrived some 50 miles from the shot point as a fine mist.

The areal extent was delineated over which the super-weapons tested could be expected to produce lethal effects. The fall-out pattern was reconstructed by the use of experimental models previously devised, based on data on high explosion model tests, together with limited gamma field data and a comprehensive analysis of the meteorological situation as it applies to particle trajectories. Certain information obtained at Operation CASTLE indicated that the determination of the radiation field from samples of sea water taken in the fall-out area may be feasible. This problem is being studied in collaboration with Scripps Institution of Oceanography under Project 2.7.

In the analysis for 6.4, the effectiveness of the washdown system was expressed as a percentage based upon the integrated dosage. By employing this base in computing the percentage, the contribution of the ambient field contamination against which the washdown system would be ineffective was included. Ambient field contamination results from the radioactive fine aerosols in the air and the contaminated sea water about the ship during the contaminating event. The findings from 6.4 data indicated that the washdown system was highly effective.

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BIOLOGICAL AND MEDICAL SCIENCES DIVISION

In response to emergency conditions in early 1954, the Biological and Medical Sciences Division participated in observations and treatment of Americans and Marshall Island natives accidently exposed to fall-out of radioactive products from nuclear weapons tests. The medical team was composed chiefly of personnel with field experience from this Laboratory and from the Naval Medical Research Institute, Bethesda, Md. Extensive skin lesions and marked changes in the peripheral blood were among the prominent signs of radiation damage. Of the formed elements of the blood, the platelets showed the most consistent response and proved to be a valuable index of hematologic depression and recovery. Long-term follow-up studies of the exposed personnel were being conducted.

At the Laboratory, investigations were continued in support of these studies and also in conjunction with regular project work in the same field and in the areas of thermal injury and therapy. Earlier work on hazards to personnel had indicated that neutrons, injury by which differs in some respects from injury by gamma radiation, could produce a considerable proportion of the total biological effect of ionizing radiation from a nuclear weapon. Neutron and gamma-ray dosimetry available for predicting biological effects were seriously limited. Clarification of these limitations promoted dosimetry work which contributed to progress in the studies of ionizing radiation and consequent biological effects, in the directions of providing quantitative data, application of new tools and techniques, and better control of variables.

BACTERIOLOGY AND IMMUNOLOGY

It was found that in mice exposed to supra-lethal doses of X rays or neutrons there is a high incidence of post-irradiation infection. However, such infection is a minor cause of death since treatment with antibiotics affects neither the final mortality nor the mean survival time. Death appears to be a direct result of the radiation itself. On the other hand, with doses of X rays or neutrons sufficient to produce 50 per cent deaths, lower infection as a secondary factor plays an important role in mortality.

Shielding of the stomach and intestines against irradiation did not prevent the post-irradiation infection in rats, thus indicating that radiation injury of the bone marrow may be chiefly responsible for the decreased resistance to post-irradiation infection. This was further supported by the fact that injections of spleen homogenate after exposure caused more rapid recovery from bone marrow injury and decreased the incidence of infection in mice.

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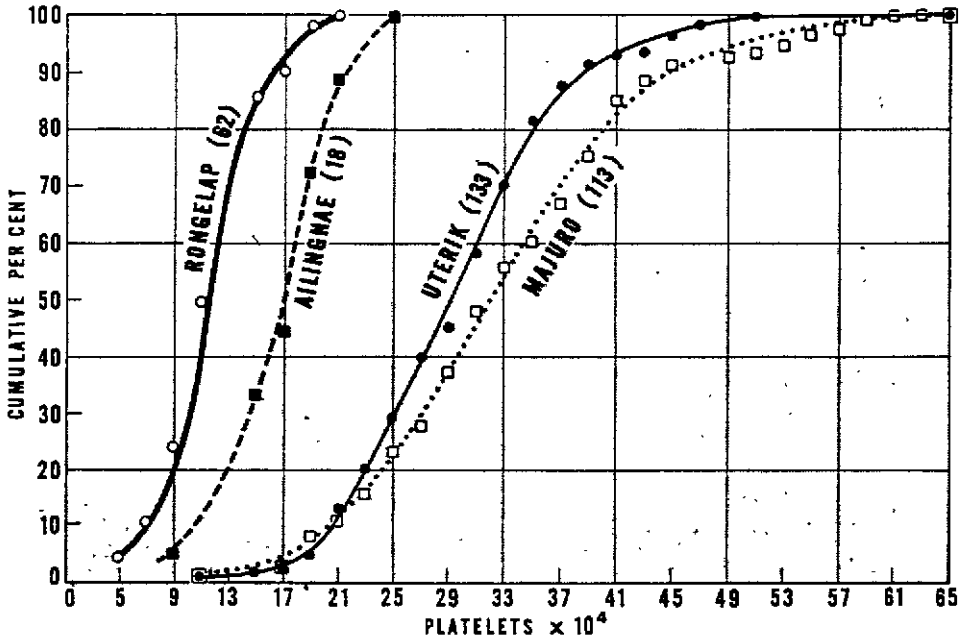

Cumulative Blood Platelet Counts (All Ages), at Time of Peak Depression, From Marshall Island Natives Accidentally Exposed to Radioactive Fall-out From Nuclear Tests. The Degree of Depression Corresponds to the External Dose Received. The Number in Each Group is Given in Parentheses After the Island Names.

The suppression by irradiation of one aspect of the immunity process was demonstrated during attempts at immunization with tetanus toxoid. Contrary to the resistance of control, immunized animals to challenging doses of tetanus toxin, there was no resistance in irradiated animals for periods of three to six weeks after irradiation, the "recovery period" being dependent upon dose of radiation received.

RADIATION DAMAGE

Data suggested that there exists a particular type of sulfur-containing protein very sensitive to radiation destruction and that the protein itself is completely destroyed by a 100 per cent lethal dose. These conclusions were based on the finding that a marked increase in urinary excretion of urea and a sulfur-containing compound, taurine, occurs upon irradiation with doses as low as 75 roentgen and reaches a plateau as the dose approaches 100 per cent lethal. That additional excretion of taurine does not ensue as the dose is increased from 100 per cent lethal to 2500 roentgen was interpreted to mean that the sulfur-containing protein is completely destroyed at the 100 per cent lethal dose. Urea excretion, on the other hand, increases much more gradually with doses greater than 100 per cent lethal, suggesting that additional, less radiation-sensitive proteins are destroyed at the higher doses.

INTERNAL TOXICITY

Internal radioactive contamination was part of the study of the human beings exposed to radioactive fall-out in the recent field tests. Related data was obtained from domestic animals, water, and soil samples collected on the contaminated atolls. At the Laboratory, study of internal toxicity of fission products focused on radioanalysis of the urine of animals exposed to atmospheres containing airborne fission products and to conditions whereby ingestion was the method of entry of fission products into the body. Field conditions were simulated by the use of aerosols of appropriate sizes derived from soil particles and by the use of early fission products derived from cyclotron and reactor pile bombardment of uranium. Studies in which chemical agents were administered to accelerate the removal of radioactive contaminants deposited in the body showed that zirconium citrate, given before a mixture of long-lived fission products was administered, most effectively prevented deposition of the latter in the skeleton. Ethylene diamine tetra acetic acid (EDTA) had relatively little effect.

PERFORMANCE OF IRRADIATED ANIMALS

Of obvious military significance is the effect on psychomotor functions by the painless, insidious radiation illness caused by acute radiation from nuclear detonations. It was found that exhaustive exercise could be performed by animals for some days following lethal irradiation.

With respect to voluntary activity there was an immediate depression of response, which data supports the concept that reduced activity is a general response to radiation exposure. In the rat, there were two distinct periods of depressed activity. The first was largely eliminated by shielding the abdomen during irradiation. The second decrease in activity was reduced by the post-irradiation injection of bone marrow.

SHIELDING AND THERAPY

The whole-body radiation syndrome in rats was analyzed in terms of component parts, through extensive comparison of the pathological effects of whole-body and various types of partial-body irradiation (of intact and surgically prepared animals) as a function of radiation dose. Injection of spleen and bone marrow preparations constitute the only known post-irradiation treatment, besides antibiotics, that decreases radiation mortality. By the use of partial-body exposure techniques, the relative ineffectiveness of spleen or bone marrow treatment in the rat as compared with the mouse was shown to be due in part to the greater radiosensitivity of the intestinal tract in the rat, resulting in an "intestinal syndrome" (not affected by therapy) at relatively low radiation doses in this species. The results obtained indicated clearly the necessity for considering intestinal and other possible lethal processes in addition to that resulting from hematopoietic injury, in order to develop effective treatments for this complex disease. Initial investigations of the lethal mechanism of the "intestinal syndrome" per se demonstrated that such deaths can be significantly decreased under appropriate experimental conditions by shielding a very short segment of small intestine during radiation exposure. A quantitatively similar degree of intestinal shielding of the otherwise whole-body irradiated, intact rat diminished early intestinal mortality so that bone marrow injection afforded protection following higher, essentially whole-body irradiation.

POST-IRRADIATION THERAPY

A single, immediate post-irradiation intraperitoneal injection of homologous spleen homogenate or bone marrow was demonstrated to reverse the radiation-induced inhibition of nucleic acid metabolism of spleen and bone marrow, as measured by incorporation of carbon-14-labeled formate into nucleic acid purines. Similarly, a single post-irradiation injection of spleen homogenate into otherwise lethally irradiated mice elicited a profound regeneration of the spleen in terms of weight and total desoxyribonucleic acid (DNA) content and concentration, concomitant with survival of these animals. These and other data from this laboratory mark the progress of investigations which have demonstrated successively the protection afforded by single post-irradiation injection of spleen or bone marrow preparations in (1) preventing mortality, (2) promoting a return to normal of spleen weights, (3) restoring formate incorporation into nucleic acid purines of hematopoietic tissues, and (4) restoring DNA content of spleen from low levels induced by irradiation

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lethal in untreated animals. These data provide evidence for the concept that the metabolism of DNA may be the key biochemical mechanism in the acute effect of ionizing radiations on living systems. It is also of interest here that the radiation protective factor in mouse spleen and bone marrow exhibits properties of a nucleic acid-protein complex.

APPLICATIONS OF THE ISOLATED LIVER PREPARATION

The technique, developed at the Laboratory, of removing the rat liver and maintaining it in a state of normal function by means of perfusion for periods as long as 30 hours, considerably facilitated a series of investigations into the effect of plasma expanders and plasma proteins on survival and bile production. It was also used in comparing in the liver, isolated and in situ, the effects of exposure to ionizing radiation under various conditions so as to try to separate direct and indirect effects of radiation exposure in this tissue.

DELAYED EFFECTS OF IONIZING RADIATION IN MAMMALS

The delayed radiation syndrome in mammals was accentuated to minimize acute radiation effects. Methods included dose fractionation, anoxia during exposure, and the application of such pre-or post-protective substances as sulfhydryl compounds, nitrites, and bone marrow and spleen homogenates. To try to unmask the latent radiation injury following more moderate total doses,specific physiological stresses were used. The delayed effects of photon and neutron exposures were compared, in doses producing comparable acute mortality.

THERMAL INJURY

In the study of combined effects of thermal and ionizing radiation, mortality from thermal burns was markedly enhanced by concomitant ionizing radiation at relatively low doses. An increased anemia, which occurred with combined ionizing radiation and thermal injury, resulted from depressed red cell production accompanying accelerated red cell destruction. A systemic effect of thermal injury alone was, in the burned rat, an accelerated destruction of red cells without the normal aging process usually seen in red cell survival patterns. Also, there were a proliferation of active red cell-producing tissue outside of the bone marrow and a hyperactivity of the normal red cell-producing centers. A significant portion of the rat red cells was destroyed by heat during the burning, which was immediate and not related to long-term effects.

It was shown, by breaking down the radiation from a carbon arc into spectral regions by means of filters, that all wave lengths are equi-effective in burn production, except for long wave length red radiation which is very ineffective. The effect of color in fabric protective layers was quantitatively evaluated. A white fabric in contact with skin allowed burns principally by transfer of radiant energy, while dark fabrics in contact allowed burns by heating and transfer of heat to skin.

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MILITARY EVALUATIONS GROUP

The Military Evaluations Group – a division attached to the Scientific Department staff – acted as a link between the Laboratory's experimental divisions and the agencies sponsoring various projects in radiological and atomic defense. The Group conducted evaluations of experimental data and applied the results to the solution of specific military problems requested by the sponsors. Where data were lacking, the Group provided interim answers based on theoretical analysis. In the planning of the Laboratory program, the Group acted as a consultant, indicating where information was lacking and where emphasis should be placed in order to obtain the necessary data.

The problems undertaken by the Group during the year dealt with the radiological defense and recovery of ships, aircraft, and land installations. The findings, supplied to the sponsors in reports and operational guides, centered around three major aspects: effects of a weapon, consequent radiological hazards, and countermeasures needed to minimize casualties or to ensure re-use of the target area under specified military conditions.

During the time that specific analyses were being conducted, the Group also continued a series of general studies which sought to add to information already developed or to refine published data for more accurate application.

PROBLEMS STUDIED IN 1954

In 1954, the Military Evaluations Group reported on such varied phases of atomic attack as:

Decontamination of Ships, Aircraft, and Structures
Prediction of Gamma Radiation from the Fall-out of an Atomic Cloud
Evasive Maneuvers for Ships Undergoing Atomic Attack
Comparison of Decontamination Methods
Hazards due to Breaks in the Integrity of Weather Envelopes of Ships Undergoing Atomic Attack
Ratio of Beta Surface rep Dose to Gamma Dose from Fission-product Contamination
Passive Defense and Damage Control for Shore Establishments
Thermal Radiation and Hazards from Atomic Bombs
Vulnerability of Advance Bases to Atomic Attack

One important result of this work has been the development of techniques for predicting the effects of atomic attack – in terms of physical damage and radiation casualties sustained if no countermeasures

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would be undertaken before and after the attack. These predictions were developed for a range of weapon yields and types of detonations, and for post-detonation periods of up to three years. Although these investigations are still incomplete, the results already achieved have enabled military organizations to design practical defense and recovery plans.

EXAMPLES OF SPECIFIC PROJECTS

Several of the projects completed during the year serve well to illustrate the kind of specific problems investigated, the method of analysis, and the extent to which a problem can be solved.

One project was to determine the radiological hazards to personnel from air-borne activity entering below-decks spaces of a ship moving through the contaminated aerosol of a shallow underwater atomic explosion. In the analysis, it was found that the ventilation system was the only path by which a significant amount of activity could reach below-decks spaces. In defining the problem, six basic assumptions concerning the nature of the aerosol, ship location, operation conditions, and stay time in the aerosol described the general situation. The theoretical analysis depended on four parameters: rate of air flow through a space; size of the space; length of time that contaminated air flows through the space; and time of exposure of personnel to contaminant.

Two extremes cases were studied in order to bracket the situation: (a) all air-borne activity entering through a duct is deposited on the deck of the space, and (b) all activity remains air-borne and flows in and out of the space. Conditions in several below-decks spaces were considered, with ventilation blowers operating and with the blowers turned off, in order to cover a range of ventilation conditions. Results of the analysis were expressed in terms of ratios of the Vent Dose (dose from exposure to activity deposited on the deck of the space below-decks) to the Transit Dose (dose on weather deck from exposure to activity surrounding the ship). Use of these ratios permits application of the analysis to any contaminating burst.

In evaluating the ratios in terms of specific radiological hazards, estimated dose values from shot Baker at the Bikini test site were used, with the following results. For case (a), external gamma doses to personnel may range from 15 to 650 roentgens, when ventilation blowers are operating at rated capacity. The magnitude of these doses depends on the parameters, and the upper limit of effects may range from incapacitation to death. Contact beta doses may range from 3,000 to 188,000 roentgens equivalent, physical, with effects ranging from reduction in combat effectiveness to possible death. If vent blowers are off, insignificant external gamma doses (5 to 50 roentgens) will result for 30-minute exposures, while contact beta exposures may result in doses large enough to produce incapacitation (14,000 roentgens equivalent, physical). For case (b), external gamma hazards are expected to

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be negligible. Internal hazards from inhalation are expected to be insignificant in causing any immediate effects, although late effects may occur.

Another project was concerned with the contamination of an aircraft carrier by shallow underwater bursts, and with the degree of decontamination necessary to enable the carrier's Air Department to carry out tactical operations as soon as possible after the attack. Tactical operations were examined in order to determine the various entry times on deck for personnel after attack and also to determine the various lengths of time that personnel would be exposed to radiation while carrying out operations. Pertinent experimental data from shot Baker and other sources were evaluated and were used along with a theoretical situation analysis to determine the radiological hazards that personnel would encounter and the doses they would receive.

From the results of the analysis, a method was developed for computing the minimum and maximum potential doses that deck crewmen and pilots would receive during a particular operation – if adequate countermeasures were not undertaken. In addition, by relating potential doses to accepted tolerance doses, this method permitted the computation of the minimum-maximum range of decontamination effectiveness required. For example, it was found that, during an interceptor operation carried out immediately after attack, the doses to deck crewmen could range from 270 to about 15,000 roentgens; the doses to pilots could range from 270 to 4,800 roentgens. These doses would be incapacitating or lethal. For personnel to carry out this operation without casualties, the decontamination methods would have to be both rapid and highly effective (96 per cent removal of contaminant).

A third project was the study of the effect of atomic attack on the ability of a port of embarkation to carry out its mission of receiving and transporting military materials. This analysis was also concerned with an investigation of the effort necessary to recover the use of the port after attack.

The main difficulty in this problem was to develop a quantitative approach to estimating the damage to facilities. Analysis developed the concept of per cent damage according to type of structure – piers, railroad cars, buildings, railroad tracks, etc. Air, surface, and subsurface bursts were studied for yield ranges of 20 to 1,000 kilotons. On the basis of data available from field tests, damage was plotted as a function of distance from burst; also plotted were contamination contours for contaminating type attacks. Information on the capabilities and resources of the port was obtained in conferences with engineering personnel at a specific port of embarkation.

It was found that the most serious effects would result from a surface detonation. Higher-yield surface bursts would damage the port over its entire area as well as deposit fall-out contamination as far as 20 to 100 miles from the burst. Hence, attack upon a port of embarkation was shown to involve much more than the port alone, since neighboring facilities and cities would also be seriously affected.

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